Water Policy 9 (2007) 545–571

Sink or Swim? Water security for growth and development

David Grey[a] and Claudia W. Sadoff[b]

[a]*Corresponding author. The World Bank, 70 Lodi Estate, New Delhi 110003, India. Tel: 91-11-4147-9402. E-mail: dgrey@worldbank.org*

[b]*The International Water Management Institute, Colombo, Sri Lanka and The World Conservation Union (IUCN), Rue Mauverney 28 - 1196, Gland, Switzerland. Tel: +41 22 999 0255. Fax: +41 22 364 9720. E-mail: claudia.sadoff@iucn.org*

Received 26 January 2007; accepted in revised form 5 June 2007

Abstract

Achieving basic water security, both harnessing the productive potential of water and limiting its destructive impact, has always been a societal priority. To capture this duality, water security is defined here as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies. This paper looks broadly at those countries that have achieved water security, the paths they chose and the costs they paid, and those countries that have not achieved water security and how this constrains economies and societies. It defines three typologies: countries that have harnessed hydrology, those hampered by hydrology and those that are hostage to hydrology. It finds that countries remaining hostage to hydrology are typically among the world's poorest. They face "difficult" hydrologies often characterized by high inter- and intra-annual rainfall and runoff variability, where the level of institutional and infrastructure investment needed is very high and the ability to invest is low.

This paper seeks to capture the dynamics of achieving water security in a hypothetical water and growth "S-curve", which illustrates how a minimum platform of investments in water institutions and infrastructure can produce a tipping point beyond which water makes an increasingly positive contribution to growth and how that tipping point will vary in different circumstances. As there are inevitable trade-offs, achieving water security is never without social and environmental costs; in some countries these are significant, often unforeseen and even unacceptable. This brief analysis suggests that the only historically demonstrated path to achieving water security at the national level has been through investment in an evolving balance of complementary institutions and infrastructure, but that lessons exist for following this basic path in more sustainable and balanced ways. Insights are provided for balancing and sequencing investments, adapting to changing values and priorities, and pushing down the social and environmental costs.

The paper concludes that most water-insecure countries today face far greater challenges than those that achieved water security in the last century and are wealthy countries today. They face more difficult hydrologies and a greater understanding of and therefore greater responsibility for, the social and environment trade-offs

doi: 10.2166/wp.2007.021

inherent in water management. As the costs of poor countries not achieving water security, in terms of human suffering, sustained poverty, constrained growth and social unrest, would be very high, achieving water security is a challenge that must be recognized and must be met.

Keywords: Development; Growth; Minimum platform; Poverty; S-curve; Water; Water resources; Water security

1. Introduction

Achieving water security by reducing its destructive potential and increasing its productive potential has always been a goal of human society and remains a central challenge for many of the world's poorest countries today. For those countries that have not achieved water security, this objective lies at the heart of their struggle for sustainable development, growth and poverty reduction.

There is now a gradually re-emerging consensus that water resources development and management are essential to generate wealth, mitigate risk and alleviate poverty; that poverty demands that many developing countries will need to make large investments in water management and infrastructure at all levels; and that this development must be undertaken, building on the lessons of experience, with much greater attention to institutional development, to the environment and to more equitable sharing of benefits and costs. The challenge is to promote growth and poverty alleviation, while at the same time ensuring both environmental sustainability and social inclusion and equity.

This paper seeks to deepen our understanding of the importance of water resources management and development[1] in enabling responsible economic growth and poverty alleviation. The dynamics of water, growth and poverty are complex and dependent upon specific physical, cultural, political and economic circumstances. In many countries, the memory of the positive role that "yesterday's" water investments played in underpinning growth has been lost, while associated, often unanticipated, costs may endure. In other countries, the future costs of "today's" water development are not recognized and irresponsible investments proceed without adequate social and environmental safeguards. This paper's broader objective is to help to inform the difficult trade-offs inherent in water management, which determine the balance between human aspirations for growth and poverty alleviation, social and cultural integrity and environmental sustainability.

2. Water security defined: growth enhanced not undermined

2.1. Water as a source of destruction and poverty — or production and growth?

Water has always played and continues to play, a central role in human societies. Water is a source of life, livelihoods and prosperity. It is an input to almost all *production*, in agriculture, industry,

[1] The term "water resources management" is understood here to include both the management and development of water resources; this appears not to be a widely understood meaning. Water resources development refers explicitly to investments that control and deliver water resources.

energy, transport, by healthy people in healthy ecosystems. Water is also a cause of death, devastation and poverty. It is a force for *destruction*, catastrophically through drought, flood, landslides and epidemic, as well as progressively through erosion, inundation, desertification, contamination and disease. This destructive aspect of water, as a consequence of its extraordinary power, mobility, indispensability and unpredictability, is arguably unique.

Harnessing the productive potential of water and limiting its destructive impact has been a constant struggle since the origins of human society. Many of the earliest civilizations, and particularly those on the floodplains of the world's major rivers, succeeded by harnessing water, often in community- and nation-building efforts that contributed significantly to the emergence of great civilizations.

Throughout history, water has also been a source of dispute and even conflict between uses and between users, particularly where water crosses jurisdictional boundaries at both local and larger scales. As water becomes increasingly scarce relative to demand there are emerging fears of inter-jurisdictional waters becoming a serious cause of conflict and constraining growth. Conversely, there is also emerging experience of cooperation on international trans-boundary waters supporting regional integration as a driver of growth and sustaining regional water security.

As then so today, developing and managing water resources to achieve water security remain at the heart of the struggle for growth, sustainable development and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in water infrastructure, institutions and management capacity. It remains the case in many developing countries today, where investments in water development and management remain an urgent priority. In some developing countries — often the poorest — the challenge of managing their water legacy is almost without precedent. Yet, if these challenges are not met, sustainable growth and poverty eradication cannot be achieved.

2.2. The concept of water security precisely defined

The term "water security" is often used but lacks, and needs, clear definition. The terms "food security" and "energy security" generally mean reliable access to sufficient supplies of food or energy, respectively, to meet basic needs of individuals, societies, nations or groups of nations[2], thus supporting lives, livelihoods and production. The term "water security" has been used reasonably in the literature with an equivalent meaning[3]. A striking difference, however, is that unlike food or energy, it is not just the *absence* of water but also its *presence* that can be a threat. This destructive quality of the resource in its natural, unmanaged state is arguably unique.

In this paper we therefore introduce a definition of water security that accounts specifically for the potentially destructive impact that water can have (Figure 1). We define "water security" to be "the

---

[2] The Rome Declaration on World Food Security and World Food Summit Plan of Action (Rome, 13-17 November 1996) defines food security in the following way, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". It should also be noted that food security is to a large extent related to water security, although this link can be bypassed through food imports.

[3] Water security has been defined as an overarching goal where: "...every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the environment is protected and enhanced" (Global Water Partnership, 2000).

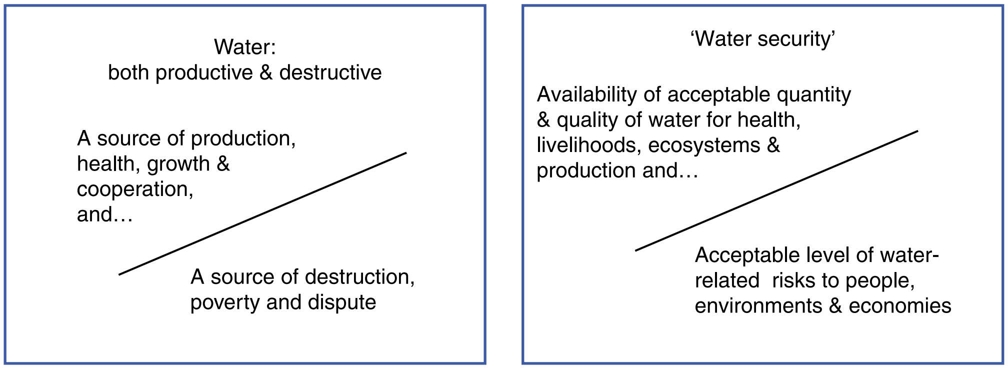

Fig. 1. Defining 'water security': water as a source of production and destruction.

availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies".

2.3. What determines water security?

The scale of the ever-present societal challenge of achieving and sustaining water security is determined by many factors, of which three stand out. First there is the hydrologic environment — the absolute level of water resource availability, its inter- and intra-annual variability and its spatial distribution — which is a natural legacy that a society inherits. Second there is the socio-economic environment — the structure of the economy and the behavior of its actors — which will reflect natural and cultural legacies and policy choices. Third, there will be changes in the future environment, with considerable and growing evidence that climate change will be a major part. These factors will play important roles in determining the institutions and the types and scales of infrastructure needed to achieve water security.

2.4. The hydrologic environment

An "easy" hydrologic legacy. Relatively low rainfall variability, with rain distributed throughout the year and perennial river flows sustained by groundwater base flows, results in hydrology that is relatively "easy" to manage. Achieving a basic level of water security is straightforward and requires comparatively low levels of skill and investment (primarily because water is sufficient, widespread and relatively reliable). Once this is achieved, growth is able to proceed without water being a significant constraint. As infrastructure platforms grow, returns from new water investments gradually diminish, water becomes a reliable input to production and water-related risks fall to acceptable levels. At this point, the need and incentives for developing new infrastructure are relatively low, while the returns from and the incentives for better managing and operating existing assets are typically high.

A "difficult" hydrologic legacy. "Difficult" hydrologies are those of absolute water scarcity (i.e. deserts) and, at the other extreme, low-lying lands where there is severe flood risk. Even more difficult is where rainfall is markedly seasonal — a short season of torrential rain followed by a long dry season requires the storage of water; or where there is high inter-annual climate variability, where extremes of flood and drought create unpredictable risks to individuals and communities and to nations and regions and require over-year water storage. The most difficult of all may be a combination of extreme intra-annual and inter-annual variability. With increasingly "difficult" hydrology, the level of institutional refinement and infrastructure investment needed to achieve basic water security becomes significantly greater. Not coincidentally, most of the world's poor face difficult hydrologies.

Poverty and hydrology: a hypothesis. Many (but not all) of the world's industrialized nations have an "easy" hydrologic legacy and were able to achieve water security early in their path to growth. Many of the world's poorest countries today are characterized by a "difficult" hydrologic legacy and, perhaps as a direct consequence of the scale of this challenge, have not achieved water security. We advance the hypothesis (Figure 2) that many societies that have inherited a legacy of "difficult" hydrology (and particularly combined inter-annual and intra-annual variability) have remained poor[4] and in a low-level equilibrium trap, in part because it has never been possible for them to make the comparatively large investments needed to achieve water security, investments that can only be resourced from the growth that water insecurity itself constrains. The global findings of Brown & Lall (2006) support this hypothesis by confirming that greater rainfall variability is statistically associated with lower per capita incomes.

A "trans-boundary" hydrologic legacy. A legacy of trans-boundary waters, hydrologic and political, can significantly complicate the task of managing and developing water to achieve water security owing to inter-jurisdictional competition both within and between nations. While this is clearly apparent in federal nations with some state sovereignty over water, it is particularly acute in the case of international trans-boundary waters. Reflecting this complexity, the UN Convention on the Law of the Non-Navigational Uses of International Watercourses was under preparation for 27 years prior to adoption by the UN General Assembly in 1997 and has not been entered into force[5]. Many of today's trans-boundary basins are the result of 20th century colonial borders that cut across watersheds and created international rivers, particularly in Africa and South Asia. In Africa, every country shares at least one international river (Guinea shares 14 rivers, Mozambique shares 8) and about half of the international rivers in Africa (28 of 64) are shared by three or more riparian countries (Sadoff *et al.*, 2003). The need for robust international institutions is great, yet the international relations challenge for a poor nation to cooperate with even one state on one river is high. There can be many lost opportunities

[4] There will be exceptions of course, in particular where major injections of external skill and capital have enabled water security to be achieved (e.g. Australia, the western United States).

[5] Nevertheless, it is now widely agreed that the major principles within the Convention reflect customary international water law.

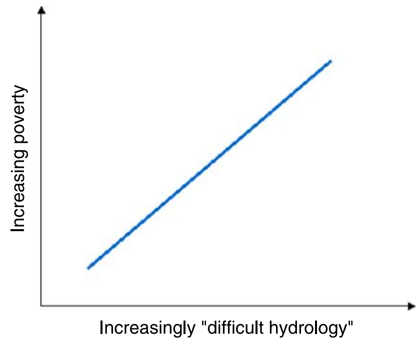

Fig. 2. Poverty and hydrology.

and increased costs, in terms of environmental costs to the river from poor management, economic costs of sub-optimal development of the river, costs from political tensions over the river and costs of all the other opportunities foregone through non-cooperation (Sadoff & Grey, 2002).

2.5. The socio-economic environment

Water infrastructure and institutions. Investments in water infrastructure and institutions are almost always needed to achieve water security. Countries with "difficult hydrology" will invariably need more infrastructure and stronger institutions, with the development of each of these being greatly complicated where waters are trans-boundary. Water infrastructure is needed to access, store, regulate, move and conserve the resource. These functions have always been performed to some degree by natural assets, such as watersheds, lakes, rivers, wetlands and aquifers and springs. In almost all societies, man-made assets have also been developed, from simple small-scale check dams, weirs and bunds that became the foundation of early cultures, to, at the other end of the scale, investment in bulk water management infrastructure typically developed by industrializing countries, such as multipurpose dams for river regulation and storage and inter-basin transfer schemes. Institutions are defined broadly to include organizations and capacity, as well as governance, policies, laws and regulations and incentives, addressing issues ranging from water allocation, quality, rights and pricing, to asset management and service delivery and their performance. In many cases, water institutions have evolved over centuries (with the water parliaments of Spain and the Netherlands being outstanding examples). Establishing or adapting water management institutions in an environment of extremely rapid technological change is a particular challenge.

Macroeconomic structure and resilience. The structure of economies plays an important role — with more vulnerable economies requiring more investment to achieve water security. Historical investments in water management institutions and infrastructure, the economy's reliance on water resources for income generation and employment and its vulnerability to water shocks will all be relevant. Water-vulnerable economies, for example those with highly variable rainfall that rely heavily on rain-fed agriculture, or those whose most productive assets or areas lie in flood plains, will require more extensive investments in order to achieve basic water security. Without investment, not only will these economies regularly suffer greater setbacks from water shocks, but this vulnerability will be likely to prove a strong disincentive for domestic or foreign entrepreneurial investments that could shift the structure of the economy toward a more diversified, water-resilient structure[6]. More diversified economies which are less water dependent and wealthier economies that can more easily insure themselves against, for example, drought or flood and compensate those harmed, might accept higher levels of hydrological uncertainty without slowing growth-focused investment. This suggests that efforts to guide structural change toward greater economic resilience to water shocks may effectively complement water investments by lowering the minimum platform of investment in water infrastructure and institutions needed to achieve water security. There is also the potential for a virtuous circle — where water investments produce gains that in turn are invested in diversified (less water-vulnerable) economic activities and water security is reinforced.

Risk and the behavior of economic actors. In the poorest countries, where survival is a real concern for large parts of the population and there are few functional social safety nets, economic actors tend to be extremely risk averse, investing only after there is significant demonstration of returns. Levels of risk aversion may therefore influence the threshold at which water security can trigger private investment. Even in "good" years, expectations of endemic droughts and floods may affect economic performance and, potentially, patterns of investment. In water insecure countries, the unpredictability of rainfall and runoff, amplified by occasional droughts and floods, is likely to constrain growth and diversification by encouraging risk-averse behavior at all levels of the economy in all years, as economic actors, particularly the poor, focus on minimizing their downside risks rather than maximizing their potential gains. Individual farm families will quite rationally not invest in land improvements, advanced technologies or agricultural inputs, thus constraining agricultural output and productivity. Lack of such investments leads to land degradation, which will result in a vicious cycle of reduced production and deteriorating assets. Similarly, there will be significant disincentives for investments in industry and services, which will slow the diversification of economic activities and maintain an economic structure that is based largely on low-input, low-technology agricultural production. Countries with "difficult" hydrology — typically the poorest countries — may well face the highest risks, yet have the most risk-averse populations, the lowest infrastructure investment and the weakest institutions. This is a serious low-level equilibrium trap, as these countries must reach higher levels of institutional development and investment, beginning from the lowest levels. Aversion to hydrologic risk is also important in rich countries, with the recent case of the New Orleans floods as just one example of how private sector reinvestment is limited by the level of confidence in the city's capacity to manage future water shocks (Jerome Delli Priscolli, personal communication).

2.6. The future environment

Climate change—making water security harder to achieve and sustain. Global climate change is likely to increase the complexity and costs of ensuring water security. Overall, climate change is expected to lead to reduced water availability in the countries that are already water scarce and an increase in the

[6] Water (in)security will create incentives and disincentives for specific economic activities in particular geographic areas, which will influence both the structure of the economy and spatial patterns of growth, and hence have an impact on overall growth and equity outcomes.

variability with which the water is delivered (Hirji & Ibrekk, 2001). This combination of hydrological variability and extremes is at the heart of the challenge of achieving basic water security. The water security challenge will therefore be compounded by climate change and it will require significant adaptation by all countries (see Sperling, 2003)[7]. This will particularly be the case in poor countries which lack the institutions and infrastructure to manage, store and deliver their water resources and where climate change will be superimposed on existing and in some cases extreme, vulnerabilities.

Adapting to the present — the key to the future. In many of the poorest countries, particularly in sub-Saharan Africa, the currently unmanaged levels of climate variability are several times greater than predicted climate change. While many developed countries are focusing on mitigating climate change, developing countries are more focused on adaptation to current climate variability[8]. Success in adaptation to variability is a prerequisite for adaptation to climate change. In all cases, however, adaptive capacity — both social and physical — will need to be enhanced to protect the poorest and most vulnerable populations.

3. Stories of water security, poverty and wealth

Are investments in water management and development a cause of growth, a prerequisite for growth or a consequence of growth? In different countries and even in the same country at different locations and points in time, the answers to all of these questions may be "yes". Water provides a range of productive opportunities, so investments in water for agriculture, hydropower and industry, for example, can be seen as drivers of growth. Water management and development can also serve to protect societies from the destructive impact of water and meet basic human needs — serving as a prerequisite for growth. And effective water management can be seen as a consequence of growth, where broader progress in governance, institutions and capacity have led to superior performance in developing and managing water infrastructure and institutions.

The economic history of water in the development and growth of nations and regions is little understood. While this could fill volumes, brief vignettes are offered here to serve as points of departure for broader discussion. They focus on specific aspects of water resources management and development that may be particularly illustrative and they include some extreme cases.

3.1. Harnessed hydrology: growth achieved in developed economies

In North America. The United States has invested trillions of dollars in hydraulic infrastructure. While these investments have been recognized as crucial to promoting growth, many of the largest federal investments in US history were made to curb the destructive effects of water, particularly in response to devastating floods. The nation's founders saw investments in water development as a way to bring the

[7] Note also that significant debate continues regarding the impact of climate change on rainfall variability, droughts and floods.
[8] Such differing perspectives have been explored by Falkenmark (2000), "It could be that the developed countries are more likely to think of environment and security in terms of global environmental changes and developing countries more with the human security implications of local and regional problems".

nation together. Early canals were major catalysts for growth and trade, spawned innovation and set the stage for western expansion of the country; the Erie Canal reduced the cost of shipping cargo from Buffalo to New York by 95%, quickly transforming New York into the largest port in the US[9].

In the early 20th century, the USA began to move to multipurpose development of water, to bring affordable electricity to rural areas while protecting against drought and flood. In 1933, the Tennessee Valley Authority (TVA) was established to foster social and economic development in the Tennessee River Valley (southeastern United States) through the integration of infrastructure, a healthy natural resource base and human capacity. The infrastructure included a system of 42 large dams and reservoirs to support navigation, control floods and produce power. This was coupled to an extensive transmission system to provide affordable electricity throughout the region. Intensive efforts to improve agriculture, land use and forestry practices helped to restore and maintain a healthy environmental base, while technical assistance and small-scale credit programs provided people with the tools to improve their own lives. In one generation, the TVA brought one of the poorest regions in the USA and the world out of poverty. It eradicated malaria and provided virtually universal water, sanitation and energy access to an area where initial access rates were comparable to those today in the world's poorest countries (Miller & Reidinger, 1998). Similar programs were implemented in other river basins, such as the Colorado, often driven by charismatic politicians and both presented and perceived as nation-building initiatives[10].

It is interesting to examine historical investments in river regulation and water storage in North America. To protect against the devastating effects of flood and drought and enable economic growth, over 6,000 m^3 of reservoir capacity per capita has been installed (this is a national average, with greater investments in highland states often serving more populated lowland states, particularly in the semi-arid western USA) — compared with 550 m^3 per capita in semi-arid Morocco and less than 40 m^3 per capita in Ethiopia, a nation wracked by flood and drought[11] (Figure 3). Hydraulic infrastructure on the Colorado River, including Hoover and Glen Canyon dams, has underpinned growth in the enormously productive economic development of the southwest, in a region of aridity and variability. The Colorado River has about 1400 days of storage, while the Indus River in monsoonal South Asia has about 30 days of storage[12]. Nationally, the US Army Corps of Engineers has spent about US$200 billion on flood management and mitigation since the 1920s. This investment has yielded an estimated US$700 billion in benefits and mitigated the impact of floods on the US economy to such an extent that flood damage has remained below 0.5% of gross domestic product (GDP) since that time[13].

While this large scale infrastructure development has had a major positive impact on growth, there have also been substantial social and environmental costs. There are serious ongoing concerns, for example, regarding the sustainability of current water-use patterns, the need for demand management

---

[9] There is much written about the Erie Canal. See: Bernstein, Peter L. *Wedding of the waters: the Erie Canal and the making of a great nation* (Bernstein, 2005).

[10] "Of all the endeavors I have worked on in public life, I am proudest of the accomplishment in developing the Lower Colorado River. It is not the damming of the streams or the harnessing of the floods in which I take pride, but rather in the ending of the waste of the region. The region — so unproductive in my youth — is now a vital part of the national economy and potential. More important, the wastage of human resources in the whole region has been reduced. Men and women have been released from the waste of drudgery and toil against the unyielding rocks of the Texas hills. This is the true fulfillment of the true responsibility of government." (future US President) Lyndon Baines Johnson, 1958.

[11] World Bank, based on data from ICOLD (2003).

[12] This estimate is based on live storage capacity and average annual flows.

[13] Jerry Delli Priscoli, USACE, personal communication.

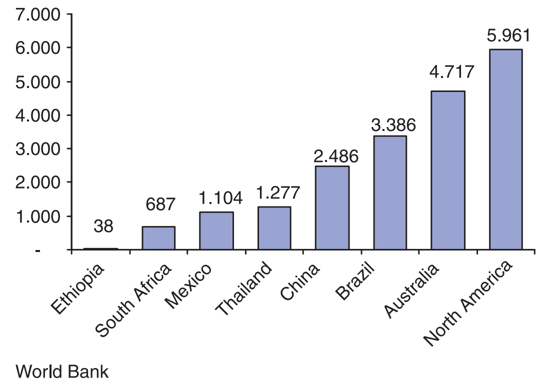

Fig. 3. Reservoir storage per capita (m^3/cap), 2003.

and dam re-operation to manage in-stream flows. There are many, recent and innovative local actions to meet these challenges. The trade-offs between growth and environmental and social change associated with infrastructure development fueled public debates in the USA on the importance of conservation, environmental standards and public consultation, debates which continue today. Environmental standards and processes for stakeholder consultation were established in the USA by the 1969 National Environmental Policy Act (after a large portion of the current infrastructure stock was built) and have since evolved under the Environmental Protection Agency (EPA).

In Western Europe. Across most of the region a predominantly temperate climate means that the risks posed by water have always been relatively small. Nevertheless, extensive investment in water storage and river regulation to supply and protect industrializing cities, the engines of rapidly growing economies, led to a relatively mature platform of hydraulic infrastructure by the early 20th century. The Netherlands is a special case where human settlement and survival has long been determined by sophisticated water infrastructure — the dykes and polders of the "low country", and sophisticated institutions — the water parliaments that were the foundation of modern Dutch democracy.

Hydropower investment is one interesting aspect of European water resources development. Significant investments have been made in Europe to develop hydropower resources, with over 70% of potential developed, in contrast to some 5% of Africa's hydropower potential that has been developed (Figure 4). France has about 26,000 MW of economically viable hydropower generation potential and has developed 25,500 MW of this. In Norway, almost all power needs are met from the 28,000 MW of installed hydropower capacity, with over 23,000 kWh per capita per year of hydroelectric power generated (some going into regional power grids). This figure is about twice the electric power consumed per capita in the USA, 10 times the world average, almost 80 times that of Ghana and roughly 750 times that of Ethiopia[14].

In recent years, at both national and European level, there has been growing recognition of the imperative to protect the environment and water quality as an integral part of water resources management. In 2000, the EU Framework Directive on Water Policy (Directive 200/60/EC) was

[14] Hydropower potentials are derived from the *International Journal on Hydropower and Dams: World Atlas & Industry Guide* (2005).

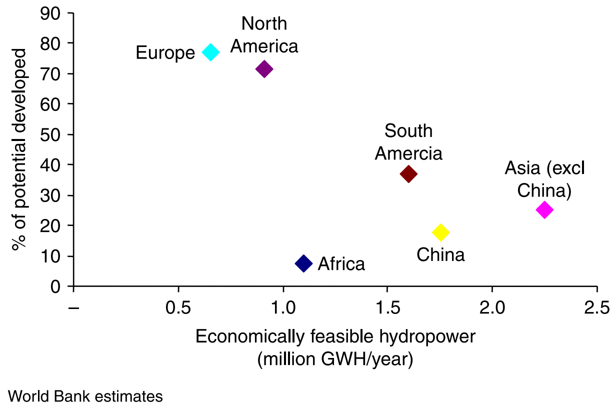

Fig. 4. Hydropower development.

adopted. This discourages the development of new dams where environmentally and economically feasible alternatives exist. The Directive also requires cooperative institutional arrangements on international rivers. The Rhine, shared by nine nations today, has long been an engine of Europe's economy and has a complex institutional structure of demarcation and use evolved through over 500 treaties since the 9th century (Dombrowsky, 2001). Even so, some inter-state tensions remain, such as a recent case between France and The Netherlands at the Permanent Court of Arbitration, relating to contamination from upstream mines in France.

In Asia/Australasia. In Japan, water and culture are closely interwoven, with a long history of water management of transport and flood mitigation. The flood plains of Japan, despite their vulnerability, host some 40% of the population and 60% of the economy's productive assets. Preliminary data show that flooding, caused by heavy seasonal rains as well as typhoons, have had a serious impact on the Japanese economy as recently as World War II, with single-year flood shocks occasionally exceeding 10% of GDP. From 1950 to 1975, some ¥ 2 trillion was invested in river infrastructure (similar to the investment in railways). Since the 1970s, a period of extraordinary growth for the Japanese economy, the impact of flood on the Japanese economy has not exceeded 1% of GDP in any year (Japan Water Forum, 2005). Even with this infrastructure stock, US$ 9 billion of public funds continue to be spent annually on flood management and mitigation.

The story of Australia is very different. Here, aridity and variability supported a pastoral lifestyle of indigenous people that was changed dramatically by colonization and the import of skill and capital in the 19th century. The independent states of Australia came together in a Commonwealth without ceding any authority over water to the federal level. Heavy investments in water institutions and water infrastructure through the 20th century underpinned the modern growth of the nation, providing power for industry[15], water for human settlement and massive agricultural and livestock production. This was not without major environmental and social costs, with blue-green algal bloom along 1000 km of the Darling River in 1991, soil salinization resulting from intensive irrigation and serious disputes between the four states and the Federal Capital Territory crossed by the Murray–Darling Basin. In recent years, the institutional framework for water management has greatly strengthened. At the national level, the Prime Minister and the Council of

[15] Tasmania described itself as the "greatest hydroelectric state of the Commonwealth".

Australian Governments are actively engaged and the National Water Commission administers federal grants to encourage better water management. At the basin level, the Murray–Darling Commission manages policy and operations in a 1 million square kilometer river basin. At the state level, water regulators and corporate bulk water service providers have been "unbundled" from state water departments. Public and private service providers operate at the irrigation district level and active water markets trade scarce water into its highest value use. However, a serious multi-year drought means that Australia's growth is once again becoming, despite all the investment, hampered by hydrology.

3.2. Hampered by hydrology: growth constrained in intermediate economies

In South Asia. In India, a country characterized by its monsoon, which causes extreme intra-annual rainfall variability, initial investment in water infrastructure had massive regional impacts with large multiplier effects on the economy. There is also direct correlation between investments in irrigation and significant declines in poverty — irrigated districts average 25% poverty rates against 70% poverty rates in un-irrigated districts and irrigation is broadly credited with sustaining the green revolution in India. The benefits of improved water resources management and institutions are similarly significant. In Tamil Nadu, for example, robust management institutions that would allow a "flexible allocation" of water between rural and urban uses could increase the state's agricultural production by 20% in 20 years, relative to fixed allocations[16]. De-linking the economy from the monsoon, however, with a combination of infrastructure, water management and economic diversification, has long been a recognized challenge. India's Finance Minister said in the 1980s "every one of my budgets was largely a gamble on rain"[17]. A recent leader headline in India was "Growth surge: no longer a gamble on Monsoon"[18], describing the shift away from agriculture and the expansion of manufacturing, communications and transport, making the structure of the economy less vulnerable to water. Nevertheless, the variability of rainfall continues to take a heavy toll across many regions of India; the 2005 monsoon claimed about 400 lives and caused US$700 million in damages in Mumbai[19] and the 2006 monsoon killed many more people, with over 130 drowning even in the desert state of Rajasthan, and 4 million people were left homeless across five states[20]. Today there is a two-track India, one with an economy in overdrive where water plays a minimal role and another, incorporating the vast majority of the population, where unreliable access to water and water shocks continue to be a central factor in persistent poverty and constrained growth.

In South Africa. South Africa, characterized by high climate variability, is an interesting intermediate case where apartheid-era water investments were made to ensure economic resilience for large-scale commercial farming, mining and financial services in the nation's heartland, while the rest (most) of the country had little water infrastructure. The Vaal River System, situated in a semi-arid region with highly variable rainfall and runoff, includes inter-basin transfers with seven other rivers systems and 16 major

---

[16] See Bhatia *et al.* (2006).
[17] *Financial Times*, June 18, 2001.
[18] *The Economic Times*, February 18, 2005.
[19] BBC News website. Payal Kapadia, August 2 (2005).
[20] Reuters, August 11 and AP, August 26, 2006.

dams; it also provides cooling water for power stations that generate about 85% of the nation's electricity (Basson *et al.*, 1994). In seven of South Africa's nine provinces, more than 50% of its water is provided by inter-basin transfers. South Africa has about 700 m^3 per capita of artificial storage, about 12% of the 6,000 m^3 per capita of North America. Arguably, however, these figures may be more similar to those in North America in that South Africa's storage investments were made to serve only a small proportion of the population. This strategy essentially provided full water security to minority-dominated growth poles within the economy, leaving the bulk of the population highly water vulnerable and without the essential services needed to grow and prosper. This was clearly inequitable, but its effect was massively reduced vulnerability and strong investment incentives in these growth poles.

Today, with pluralism and democracy, this wealth is being spread, high growth rates are being sustained and there are major shifts in societal values. For example, in recent legislation, specific flow allocations in each river basin are mandated for basic services to the poor and for in-stream environmental flows, before other allocations are considered.

3.3. Hostage to hydrology: growth stalled in developing countries

In Ethiopia. Hydrological variability seriously undermines growth and perpetuates poverty in Ethiopia (World Bank, 2006). The economic cost of hydrological variability is estimated at over one-third of the nation's average annual growth potential and these diminished rates are compounded over time. Yet, with much greater hydrological variability, Ethiopia has less than 1% of the reservoir water storage capacity per capita of North America to manage that variability. Economy-wide models incorporating hydrological variability show that projections of average annual GDP growth rates in Ethiopia drop by as much as 38% as a consequence of this variability[21]. In Ethiopia, so sensitive is economic growth to hydrological variability that even a single drought event within a twelve-year period (the historical average is every 3–5 years) will diminish average growth rates across the entire 12-year period by 10%. The effects of hydrological variability emanate from the direct impact of rainfall on the landscape, agricultural output, water-intensive industry and power production. Because Ethiopia lacks the water resources infrastructure and institutions to mitigate hydrological variability directly and it lacks the market infrastructure that could mitigate the economic impacts of variability by facilitating agricultural trade between affected (deficit) and unaffected (surplus) regions of the country, impacts are transmitted and amplified through input, price and income effects onto the broader economy. The overall impact is that Ethiopia's economic growth is tied tightly to the rains (see Figure 5)[22].

[21] This estimate is based on the results of a stochastic, economy-wide multi-market model that captures the impact of both deficit and excess rainfall on agricultural and non-agricultural sectors. The results show growth projections dropping 38% when historical levels of hydrological variability are assumed, relative to the same model's results when average annual rainfall is assumed in all years (which is the standard modeling assumption) (World Bank, 2006).

[22] This graph presents a correlation that does not necessarily prove causality. An interesting question raised by this graph is why excessive rains are not associated with lower GDP growth. One possible explanation might be explored from the case of Kenya (see World Bank, 2004). Here the majority of economic costs from drought are losses in agricultural incomes, whereas the economic cost of floods is manifest in infrastructure damage (i.e. roads and bridges). In the calculation of GDP, agricultural losses directly diminish GDP. However infrastructure damage, if it were immediately repaired, could be recorded as investment in the national accounts which would actually increase GDP and explain why excessive rains appear to be associated with strong growth.

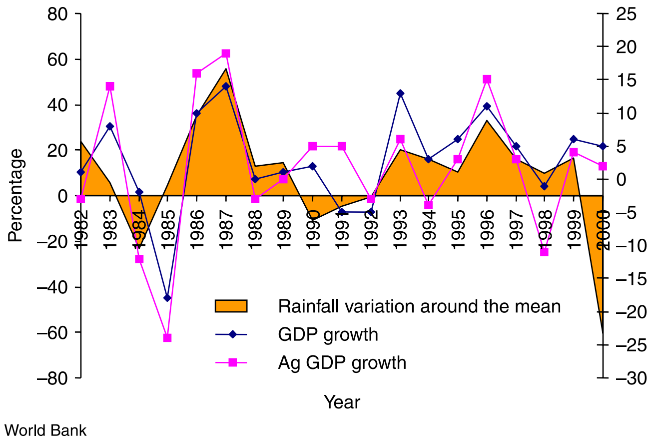

Fig. 5. Rainfall, GDP and agricultural GDP for Ethiopia.

3.3.2. In Yemen. Water and poverty are closely linked in Yemen (World Bank, 2005). Groundwater overdraft, degradation of watersheds and low access to safe water and sanitation are all principal causes of poverty in the country. Yemen has no perennial surface water and depends entirely on rainfall, groundwater and flash flooding. By world standards, Yemen is a country that is poorly endowed with water resources. Even compared to other countries in the Middle East, Yemen has among the lowest rates of per capita freshwater availability (150 m^3 per capita per year) and one of the highest rates of water use in agriculture. Moreover, this relative water scarcity is exacerbated by significant physical and temporal variations. With the population projected to double, water availability per capita will decrease by 35% by 2025, well below levels generally considered to indicate severe water stress.

There is firm evidence that Yemen has been overdrawing or "mining" its groundwater resources for many years. Groundwater use began to exceed recharge in the mid-1980s with more than 80% of abstraction going to irrigated agriculture. In agriculture and irrigation the status quo appears to be unsustainable and anti-poor. Water access is inequitable and *de facto* water rights patterns and water mining practices exacerbate inequalities. With the continued mining of groundwater in all regions of Yemen, some areas will almost certainly lose their economic viability and even their drinking water supplies may become inadequate, resulting in unsustainable livelihoods, displacement and resettlement. Government policies initially promoted the rapid development and utilization of water resources. By the early 1990s the severity of the water shortage and a growing fiscal crisis became evident and now the scarcity of water and economic crises are forcing change. Today, Yemen is enduring a water crisis that ranks amongst the worst in the world.

4. Insights from the struggle for water security

These stories, together with many other observations suggest that we would expect to see a world in which societies are relatively poor where water is scarce or in excess, and/or water availability is highly seasonal and/or variable, because basic water security has not been achieved and a minimum platform is not in place. On the other hand, we can expect to see a world in which societies are relatively rich where water is sufficient, widespread and reliable and water security was easily achieved — mostly in temperate climates with low rainfall seasonality/variability. Most of those countries that have not achieved water security face difficult hydrological legacies and insufficient institutions, capacities and infrastructure stocks with which to manage and deliver water. They are therefore in a "deep hole"; getting out of that hole will be difficult and costly. These experiences further suggest that there is a minimum platform of institutions and infrastructure that is needed to achieve water security and that there is a marked difference between countries with "easy hydrologies" (mainly rich countries today) and those with "difficult hydrologies" (mainly poor countries today.) There will of course be other reasons why societies are poor or rich, but hydrologic legacy, water investment and water security are together significant factors and this is little recognized.

4.1. Water harnessed, hampered by water or hostage to water?

Hydrology is harnessed in most industrial countries, where the flows of almost all major rivers are regulated and managed, storing water for multiple uses, reducing peak flows, increasing low flows and protecting water quality, thus reducing the risk of water-related shocks and damage, increasing the reliability of water services for production and reducing other negative impacts, such as disease. Many, but not all, industrial countries, have an "easy" hydrologic legacy, implying that societies that did not have to combat an adverse climate regime had one less development barrier to overcome, facilitating earlier, easier growth. Although varying widely, institutional aspects of water management are typically embedded in society and in the political structure of governments and have often evolved over considerable time. Early and large investments have been made in bulk water infrastructure and in the human capacity required to operate and maintain these investments. In most cases, the infrastructure platform is mature (and even over-invested in some cases) and much greater emphasis is placed on water management and infrastructure operations, both to maximize the returns on infrastructure investment as well as to respond to shifting societal priorities, where increasingly high values are placed on environmental and aesthetic assets. These investments in institutions and hydraulic infrastructure were clearly a precondition to *harnessing hydrology* for sustained and broad-based growth and development.

Hydrology hampers most intermediate economies, where much investment has typically taken place in water infrastructure. In some countries, substantial water investments have been made to promote growth (such as in hydropower and irrigation infrastructure), but the economy is still vulnerable to catastrophic shocks (such as those of floods and droughts) which continue to have a major impact on growth. In yet other cases, financing has been available to build infrastructure but institutional and human capacity is inadequate or has not sufficiently adapted to manage water resources and new infrastructure effectively. These varied circumstances underscore the imperative of balancing and sequencing investments in both the institutions and the infrastructure required to manage water resources effectively. While it is likely and understandable that countries initially will place a premium on physical capital investments, human capacity and institutions can take much longer to build and adapt. The right balance and sequencing of these investments will be dynamic and highly context-specific[23]. Getting this balance right will be crucial for leveraging and sustaining growth that may now be *hampered by hydrology*.

---

[23] At the 2005 World Water Week there was a strong consensus that "What may be an appropriate approach and solution in one site and for a well defined problem is not necessarily benign in a wider setting". See SIWI (2005).

Hydrology holds hostage many least-developed economies, which have inherited a "difficult" hydrologic legacy of intra-annual and inter-annual rainfall variability and/or rainfall extremes, coupled with a massive water-related disease burden, while the capacity, institutions and infrastructure needed to manage and mitigate these potentially major challenges are generally inadequate. Catastrophic hydrological events such as droughts and floods often have dramatic social and economic impacts, with declines in annual GDP often exceeding 10% and there being tragic losses of life. What is less apparent is that, as a consequence of widespread expectations that these unmitigated catastrophes will recur, risk-averse behavior and disincentives to investment become pervasive. Such behavior can seriously undermine economy-wide investment and hence growth even in years of good rainfall. At the sectoral level, we see many consequences of weak water management, such as unpredictable food production caused by climate variability, health impacts of poor water supply and sanitation, unreliable electricity supplies and a poor investment climate owing to water-affected transport and energy infrastructure. In many of the world's poorest countries, climate variability is high, water-related investments are relatively limited and there is often a strong correlation between hydrology and GDP performance. This is particularly true in rain-fed agrarian economies and appears to be a statistically significant phenomenon globally (Brown & Lall, 2006). Where economic performance is closely linked to rainfall and runoff, growth becomes *hostage to hydrology*.

4.2. Balancing and sequencing institutions and infrastructure

The development of water institutions and infrastructure must go hand-in-hand. Historically it has generally been the case that water systems have evolved slowly and in a reasonably balanced manner. However, the rapid technological advances of the 20th century have often outpaced institutional capacities. The case of groundwater is illustrative, where the cultural practice and customary law of groundwater development was well-adapted to technologies which did not allow substantial groundwater abstraction from any but very shallow depths. With the rapid and worldwide adoption of motorized drilling rigs and pumps in the second half of the 20th century, allowing higher pumping rates from greater depths, a groundwater development revolution has taken place. Yet groundwater management institutions, policies and practices have not evolved or adapted in many countries, resulting in massive groundwater over-abstraction and degradation with serious and sometimes almost irreversible consequences.

Infrastructure will not deliver high, sustained returns if it is not well designed and managed and managers will not be able to optimize the use of the resource without adequate (natural or man-made) infrastructure. Similarly, strong institutions and sustainable governance will also directly contribute to appropriate investment in and proper operations and maintenance of, sound and reliable water infrastructure. For effective water management, institutional design needs to ensure inclusion, accountability and equity and be flexible enough to adapt to change, such as in technologies and social policies. Experience again and again demonstrates that investments in institutions and infrastructure must be made in concert, with their relative weight or priority a question of degree only.

The balance between infrastructure and institutional investments will differ between countries and failure to understand this within the context of specific country circumstances can lead to poor investment choices (Figure 6). In most developed countries significant infrastructure investments have been made (in some cases arguably excessive investments) and much greater returns are now derived from improving water resources management and infrastructure operations. In some of the world's poorest countries, infrastructure stocks

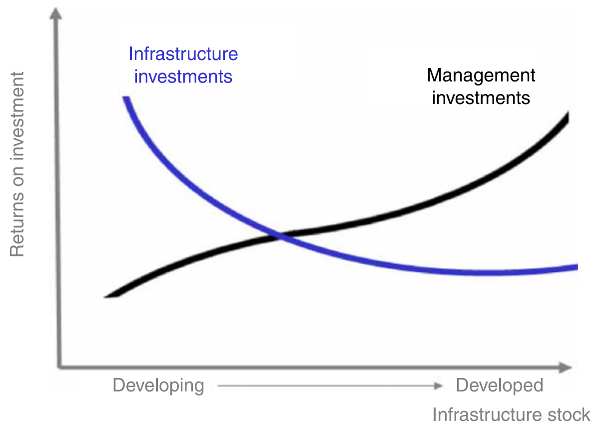

Fig. 6. Balancing and sequencing investments in water infrastructure and management.

may be so low that investments in management will not have significant returns. Without the infrastructure to store and deliver water and manage flows, water managers and institutions, no matter how sophisticated, are severely constrained. This suggests that while developed countries with ample infrastructure stocks are appropriately focused on water management and infrastructure operations, in some developing countries it will be appropriate to place greater emphasis on infrastructure investments, just as developed countries did at a similar point in their development, but with the added advantage of drawing on global good practice to do so, proactively building institutions to match the need.

4.3. A minimum platform for water institutions and infrastructure

The idea of a "minimum platform" for water institutions and infrastructure is central to water security. Below a minimum platform, a society is highly vulnerable to water-related shocks. This means that economic growth cannot be reliably and predictably managed, which is a significant obstacle to growth. When basic water security is achieved, societies are sufficiently resilient to the impact of water so that water underpins, rather than undermines, growth. Once an acceptable level of water security has been achieved, if further investments are made they tend to be focused more on growth enhancement, rather than on meeting unfulfilled basic needs and mitigating risks. Additional investments can also enhance water security, which is a dynamic condition: different in different parts of the world (reflecting geographic, climatic, social, epidemiological, economic and political factors) and changing over time as many of these factors shift with development.

What we believe we are seeing in the dynamics of water security can be illustrated in a hypothetical water and growth "S-curve" which illustrates how a minimum platform of investments in water infrastructure and management can produce a "tipping point" beyond which water makes an increasingly positive contribution to growth. The "S-curve" suggests that early incremental returns on investment in water resources, perhaps particularly in countries with high hydrological variability, may appear to be fairly low. It is posited that a significant public investment may be needed before basic water security is achieved and unconstrained growth ensues, much like a road investment which may have little return until it joins two towns[24]. Point "a" in the diagram (Figure 7) marks the "minimum platform" level of investment at which a country with "easy" hydrology achieves water security, after which rapid growth is seen. Prior to this tipping point the returns on such investment are fairly modest. Point "b" marks the "minimum platform" of investment at which a country with "difficult" hydrology reaches water security, suggesting that countries with more difficult hydrology require greater upfront investment in infrastructure, institutions and capacity — which may initially provide relatively low returns — in order to achieve water security. The standard assumption would be that there is an initially high and then gradually declining return in growth from investment in water infrastructure and institutions. The S-curve illustrates an alternative hypothesis[25] that may reflect the reality of some, but not all, countries.

Many factors will influence this dynamic. The need for a higher minimum platform of investments could be a consequence of a more "difficult" hydrology, a more water-vulnerable economy, or a more risk-averse population — all of which puts the country in a "deeper hole" as it tries to mitigate variability and achieve a basic level of water security. If governance or capacity is particularly weak, the political economy of institutional reforms will also affect the dynamic of this hypothetical curve, shifting the "S" outward — calling for a higher level of investment — with increased resistance to reform. On the other hand, better technologies and more efficient management policies (e.g. demand management and pricing) may lessen the need for investment, either shifting the "S" inward or achieving the concave curve which is generally assumed for early investments.

The "S-curve" can also be used to illustrate the differences in water security scenarios (Figure 8). Developing countries will generally be along the lower, water-insecure or water-vulnerable horizontal segment of a "difficult" hydrology S-curve. Intermediate economies are often along the steep, tipping point segment and developed economies are generally along the upper, water-secure horizontal segment.

4.4. Trans-boundary institutions: threat or opportunity?

Trans-boundary rivers present yet another layer of complexity in the design and balance of water infrastructure and institutions. Developed economies have in most cases achieved a relative equilibrium in establishing fit-for-purpose trans-boundary institutional arrangements, including treaty regimes with co-riparian states that deal with issues of river infrastructure and the quantity and quality of water flows. In basins in developing regions, nations have often unilaterally developed trans-boundary rivers within their own territories, settling for second or third best investments from an unconstrained basin-wide perspective because the complexity (and associated cost) of cooperation

---

[24] If this is in fact the case, it has important implications for the way in which we assess the cost-effectiveness of early investments in water resources infrastructure. Standard tools of project economic analysis may be problematic for many reasons: they focus sharply on marginal rates of return which may be misleading if applied to large inter-related, multipurpose water infrastructure systems; and they assess only direct costs and benefits without capturing forward linkages and multipliers and the impact of basic water security on private sector investment responses. Such tools are generally inadequate to capture the potentially transformational impacts of large-scale, multipurpose investments. See Hirschman (1958), Bhatia *et al.* (2005) and Reuss (2003).

[25] This is an untested hypothesis for discussion, for which there is some strong anecdotal evidence.

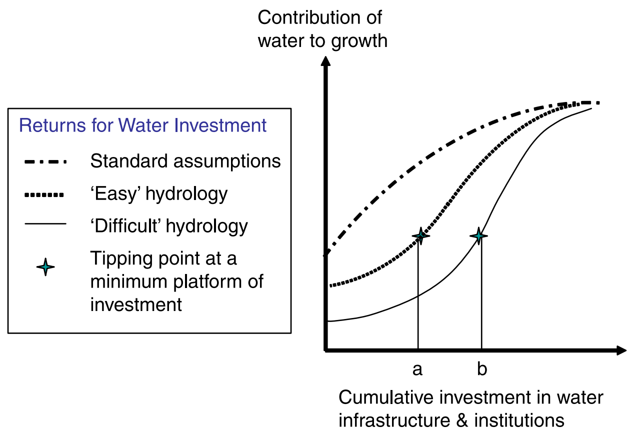

Fig. 7. Water and growth S-curve.

proves too great a deterrent. In many cases, however, the need for river infrastructure, such as locks for navigation or weirs and dykes for flood management (e.g. the Rhine) or hydropower facilities (e.g. the Columbia River), have proved to be primary drivers for adopting cooperative institutional solutions. In the second half of the 20th century, with water quality a growing concern, there has been an increasing emphasis on joint institutional solutions to restore riverine and lacustrine ecosystems (e.g. the Rhine and the Danube)[26]. Increasingly, cooperative efforts are focusing on the sharing of benefits, rather than water. Where water allocations are generally perceived as zero-sum negotiations, cooperative management provides opportunities to increase the scope and scale of benefits from international rivers — benefits that can then be shared by mutual agreement[27]. The shared benefits of cooperative management (say for flood management and mitigation, or for water quality) and development (say for irrigation and power) can provide the incentives to establish and sustain trans-boundary institutions.

5. The challenge of achieving water security in the 21st century

History demonstrates that achieving water security has always been an early priority for societies and will always be a priority for water-insecure nations. In the 21st century, however, this challenge must be met by building on the environmental and social lessons of the past. The once unforeseen consequences of environmental change and social displacement have been clearly identified and documented and cannot be responsibly ignored. On the other hand, setting environmental and social standards so high that they greatly constrain, or even prevent, achieving water security is equally unacceptable. There are always some tradeoffs, which need to be identified and debated by

[26] This trend is clearly demonstrated in Lautze & Girodano (2006).
[27] Benefit sharing also provides riparians with the flexibility to separate the physical distribution of river development (where activities are undertaken), from the economic distribution of benefits (who receives the benefits of those activities). This allows riparians to focus first on generating basin-wide benefits (a positive-sum exercise) and second on sharing those benefits in a manner that is agreed as fair. See Sadoff & Grey (2005).

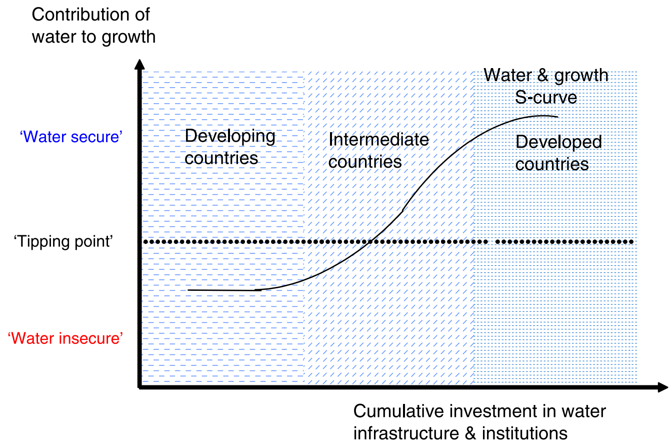

Fig. 8. Water security scenarios.

governments and their citizens and, to the extent possible, mitigated. The active and often contentious development debate on water infrastructure would be greatly facilitated if those in developed countries reflected upon the path that they have taken to achieve water security and those in developing countries considered the lessons of countries that have achieved water security at high and unnecessary social and environmental costs.

5.1. Balancing natural assets, managed assets, man-made infrastructure

Natural water assets have always been valued by societies which have sought to manage, enhance and replicate their functions. Early societies arose along rivers and lakes because these natural assets provided significant water security for domestic use, irrigation, transport fisheries and power (from water wheels to hydropower). As populations and water demand have grown, man-made infrastructure became necessary to supplement natural assets in order to maintain water security; there is evidence of dams built over 4,000 years ago to store water in ephemeral rivers (Fahhlbusch, 2001). In countries with adequate wealth and technology, dams, wells, canals, pipelines and municipal water supply systems have been built to provide storage and delivery functions like those of lakes, rivers and springs and treatment plants that provide the cleansing functions of wetlands and aquifers. From natural to man-made and from small-scale to large, a continuum of options has evolved to meet the challenge of water security.

While natural water assets have always played a key role in the achievement of water security, the full range of their environmental values are increasingly being recognized and incorporated into the design and management of man-made water assets as well. The management of environmental flows, managed flooding of wetlands and flood recession and fish ladders at dams, weirs and locks are all examples of innovations in infrastructure design and operations that seek to achieve the socio-economic and environmental values associated with natural assets. This recognition and societies' willingness and ability to invest in environmental values, are likely to grow in the new millennium.

5.2. Changing priorities, changing objectives

As countries grow and the welfare and dignity of their populations become more secure, their priorities and therefore relative values change. This may be especially true for water resources management (institutions) and development (infrastructure). Writing in 1946, Gandhi believed that all India's rains should be stored so that famine could be overcome[28]. Writing in 2003, Martin Reuss of the US Army Corp of Engineers describes the trend in water resources planning objectives in the USA as increasingly setting limits to growth by placing high value on non-human needs[29]. Evolving societal values and economic growth in Canada have led BC Hydro to re-engineer its hydropower structures, placing high value on improved in-stream flows and fisheries, at some (although not great) cost to hydropower production (Daryl Fields, personal communication). A downstream nation on the Rhine at great risk from flooding from the river as well as from inundation by the sea, the Dutch have struggled to shift from control of society by the river (the Rhine floodplain in the 19th century occupied 85,000 ha), to control of the river by society (with the floodplain constrained to 30,000 ha), to a new strategy that makes "room for the river" (moving the dykes further back from the river), seeking a more adaptive balance between the river and society.

In many industrial countries, often following periods of significant economic growth, there is a great deal of emphasis on re-operation, re-engineering or even dismantling of existing water infrastructure systems to optimize performance and to meet evolving environmental and social priorities. Many developing countries, on the other hand, find their infrastructure stocks to be inadequate and therefore see an overarching imperative to invest in new water infrastructure in an attempt to reduce the destructive costs and increase the productive value of water in their economies[30]. The social and economic cost of not developing water, simply maintaining the status quo, will be high where many people are physically vulnerable and live in life-threatening poverty. There is thus a clear willingness in many developing countries to face the trade-offs required to further these goals, mitigating their inevitable costs by the pragmatic application of social and environmental safeguards. As economies grow, these trade-offs may become less stark, both because economic security lowers the cost of inaction

---

[28] "In this land of ours, fabulously rich in natural resources, there is the lofty Himalayas with its ever-lasting snows where, they say, dwells the Lord of the Universe. It has mighty rivers like the Ganges. But owing to our neglect and folly, the year's rains are allowed to run down into the Bay of Bengal and Arabian Sea. If all this water was trapped and harnessed for agriculture purposes by the construction of dams and tanks, there should be no famine or food shortages in India". Mahatma Gandhi, 1946.

[29] "Replacing both the scientific efficiency model of the early 20th century and the more recent economic efficiency model is an approach that I can characterize only as planning by constraints. The process emphasizes regulation and focuses on water quality, rather than quantity, issues. Rather than maximizing economic efficiency or optimizing the opportunity to meet public objectives, it sets limits to growth. To what extent it remains basically an anthropocentric process, in which sustainable development is justified economically as well as morally, or reverts to a biocentric ethic which grants to other living things a moral worth equal to that of the human population, is a great question. Certainly, any process that grants inherent moral worth to non-humans establishes a system of competing claims that ultimately sets limits on human population, patterns of consumption and technological development. Any equitable solution to these problems of competing claims with non-humans would require the application of a system of ethics and a notion of justice that substantially modifies the value system of western civilization". Martin Reuss (2003).

[30] During World Water Week 2005: "Many high-level public officials emphasised during the week that investments in hydraulic infrastructure are a basic necessity for economic growth in many developing countries. Infrastructure helps in coping with rainfall variability and climate change and in achieving long-term water security". See SIWI (2005).

and because mature infrastructure systems offer greater scope for re-engineering and re-operations that will meet evolving, multiple objectives with less social and environmental disruption.

This path of shifting values is obvious, yet commonly unrecognized. In an increasingly globalized world, there are pressures on developing country institutions to adopt developed country priorities and standards. Within this dynamic, however, the immediate and often extreme growth and poverty challenges faced by developing countries — and consequently their values — may not be recognized by developed countries, whose domestic priorities may be on water management as they already have a mature infrastructure platform. At the same time, developing countries, whose priorities may be on water infrastructure, may not fully appreciate how greatly their values and priorities are likely to shift with growth and therefore do not recognize this in their planning, making decisions which they may soon regret. It is important that donor perspectives do not obscure the priorities of developing countries and, at the same time, it is important that developing countries ensure the development and adaptation of water management institutions in parallel with their infrastructure investments.

5.3. Pushing down the social and environmental costs of water development

In all developed countries early and large investments were made in achieving water security, but the social and environmental costs were often high. Experience in many developing countries demonstrates that social and environmental costs of water insecurity are also very high. Poverty and social unrest, both of which are aggravated by the lack of water security, generally lead to environmental degradation. Efforts to protect the environment by forgoing water security may therefore prove to be self-defeating. Where water security has not yet been achieved, hindering water development could well lead to stagnant or falling incomes and environmental and social harm all the same[31]. Moreover the poor are those who are generally most vulnerable to the destructive impact of water and those with the least opportunity to exploit the production opportunities that water can provide — suggesting that absolute inaction may in fact be intrinsically anti-poor. On the other hand, achieving water security with poorly developed water infrastructure can have very high social and environmental costs, causing environmental degradation and social unrest and even aggravated poverty, particularly among people directly affected, such as those displaced.

To illustrate this point we use a graphic that recalls the Environmental Kuznets Curve (EKC). The EKC is conceptually derived from Simon Kuznet's famous curve showing income inequality first rising and then declining as per capita incomes grow. The EKC substitutes a range of environmental quality indicators for the original measure of income inequality and finds the same inverted "U" relationship with per capita incomes[32]. We posit a similar relationship between environmental and social disruptions associated with water management and development at different income levels. It has generally been the case, as represented by the rising portion of the curve labeled "historical investment paths", that early

[31] See the World Bank (2003) discussion of the development cost of inaction.

[32] Barbier (1997) points out that the EKC relationship probably reflects the dynamics of structural economic change on the use of the environment, the link between the demand for environmental quality and income and the specific types of environmental degradation and ecological processes. We do not address the debate on the validity of the EKC.

investment in water infrastructure incurred high social and environmental costs. As incomes grow, there will be more options, technologies, resources and public pressures to mitigate and compensate for the economic and social costs of water development, reflected by falling overall costs at higher national incomes (Figure 9).

Where water security has not yet been achieved and populations continue to grow, a lack of investment in water security may lead to stalled or diminished incomes while environmental degradation and social disruption increase anyway as a consequence of water-related crises, population pressures and poverty. This alternative is reflected by the set of dashed paths characterized as "no action to address water security".

This does not necessarily mean that poorly-designed water development is better than no water development at all, but it does mean that no water development in water-insecure nations will be worse for society and the environment than well-designed water development. "Good" water development will follow a thorough examination of *all* options: actions and inaction; water conservation and water development; natural and man-made infrastructure at all scales; alternative technologies, incentives and institutions; capacity building and so forth.

One key lesson is that there is no fundamental constraint to designing water development investments that ensure that local communities and the environment equitably share real benefits in current and future generations, while still allowing the economy and society at-large to benefit from the growth made possible by these investments. This requires stakeholder consultations on costs, benefits, rights and responsibilities, and environmental flows and an understanding of the economic and distributional impacts of water development, particularly on the poor. In order that future generations inherit institutions and infrastructure that will adapt readily to their evolving values, scale, site selection and operational characteristics need to be assessed from a long-term planning perspective, incorporating anticipated trends and emphasizing adaptability. Building on this lesson, enhanced by local and indigenous knowledge and consultation, there is great potential, and an imperative, for developing countries seeking to achieve water security, poverty reduction and growth to "push down" the stylized Kuznets curve, by greatly lowering environmental and social impacts (Figure 10).

Lessons, principles and guidelines. There are many lessons of experience, which have led to the development of standards and guidelines for reducing social and environmental costs. A great deal

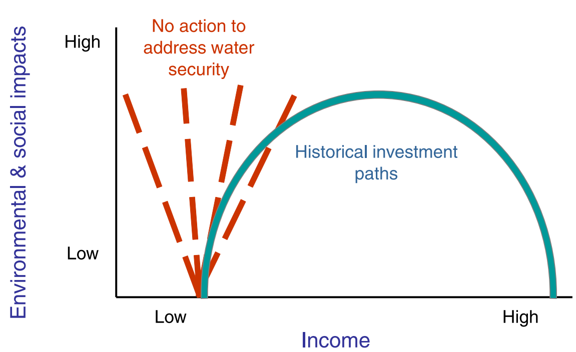

Fig. 9. Stylized environmental Kuznets curve: incomes and environmental impacts.

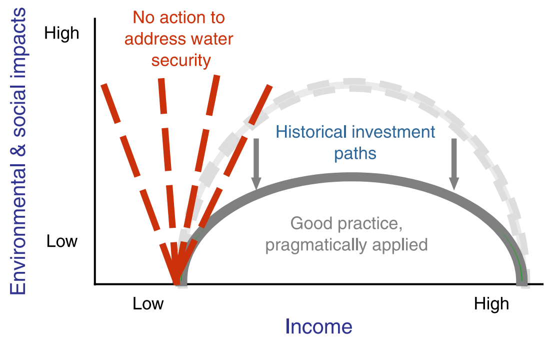

Fig. 10. A stylized environmental Kuznets curve: minimizing environmental and social impacts.

of progress has been made in water resource management, with a broad global consensus on the principles, emerging from the Rio Earth Summit (1992) and initiated as the "Dublin Principles"[33]. International standards and safeguards are continuously evolving, with a growing body of tools that can assist, such as the recommendations of the World Commission on Dams and the International Hydropower Association and the environmental and social safeguards of the World Bank. These lessons may also lead to new development paths, both in terms of the way we manage our water resources and the way we manage water usage within our economies, which will not unduly constrain growth and development, yet will uphold evolving societal values regarding equity and the environment.

In addition to the likely imperative to develop and manage hydraulic infrastructure, there are important institutional lessons as well, emphasizing the need to focus on resource management, economic resilience and social inclusion and equity.

Focus on resource management. Multi-disciplinary advancements have broadened the range of adaptive management options available. Allocation mechanisms, such as water rights and regulations and water pricing and fees, are used to ensure better management of both the quantity and quality of water resources. Important evolving practices include innovations in environmental and social impact analyses (particularly of local project-affected populations and environments), in-stream flow management, environmental set-asides, demand management, re-engineering and re-operations, enhancement of natural water storage and regulation and benefit sharing with affected populations and trans-boundary neighbors. Water institutions that promote equity, efficiency, participatory decision-making, sustainability and accountability will facilitate achieving and sustaining water security[34].

[33] The Dublin principles were adopted at the International Conference on Water and the Environment (ICWE) in Dublin, Ireland in January 1992. They are as follows: Principle No. 1 – Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Principle No. 2 – Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels. Principle No. 3 – Women play a central part in the provision, management and safeguarding of water. Principle No. 4 – Water has an economic value in all its competing uses and should be recognized as an economic good.

[34] These are the five core values defined by the World Commission on Dams (2000).

Focus on economic resilience. In water-insecure nations, there may be potential for managing the economy to make it less vulnerable and more resilient to water shocks. Increased investment in more water-resilient sectors, settlement and production in areas with less water stress or climate variability, water pricing which provides appropriate incentives, trade in "virtual water" (Allan, 2003) and greater economic diversification more generally could all diminish an economy's vulnerability to water shortages and shocks. This would lessen the need for water development and accelerate the achievement of water security.

Focus on social inclusion and equity. An enduring challenge in water management and development decisions is to balance the aspirations of society at large with protection of individuals, in the context of the larger socio-political arena. This requires understanding and support for the challenges of affected groups, disenfranchised people and women. Strategies and tools are continuously evolving for more effective social and gender impact analyses and safeguards, successful development communications, broader inclusion and greater transparency. The engagement of civil society and ensuring equitable benefit sharing are likely to lead to more sound investment choices and diminished social costs in the achievement of water security.

6. Conclusions

In this paper water security has been defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies. Water security has always been a societal priority — in its absence people and economies have remained vulnerable and poor.

The only demonstrated path to achieving water security at a national scale has been through investment in an evolving balance of complementary institutions and infrastructure for water management. If poor countries, where water security has not been achieved, are to grow and to lift their people out of poverty, is there a viable, fundamental alternative to achieving water security? This brief analysis suggests that there is not. But there has been a steady process of learning and innovation that provides numerous lessons for following this basic path in a more sustainable and balanced way. Both good and bad experiences provide insights for all countries to strengthen institutions and management capacity and ensure better design of new (or operation of existing) water resource infrastructure.

Achieving water security is never without costs, as there are inevitable trade-offs involved in water development. It is clear that some countries have achieved water security at significant and often unforeseen and even unacceptable social and environmental costs. For this reason, poor countries must not see water infrastructure alone as a panacea. Without the development of appropriate water institutions, badly managed infrastructure will probably not support growth; it (and its associated debt) may even forestall growth. Every effort must be made to ensure that the costly mistakes of the past are avoided in the future.

Drawing on international experience, insights are provided for better balancing and sequencing investments in water infrastructure and institutions designed to adapt to changing values and priorities, for considering all potential options and then tailoring these choices to country-specific circumstances and for pushing down the social and environmental costs of achieving water security. These insights are increasingly becoming accepted good practice guidelines that need to be applied in a pragmatic way to ensure that all countries attain water security.

The paper concludes that most poor, water-insecure countries face a far greater challenge than faced by those that had achieved water security in the last century and are wealthy countries today. Today's water-insecure countries face more difficult hydrologies, much larger populations with more varied water demands and a greater understanding of and therefore greater responsibility for, the social and environment trade-offs inherent in water management.

In this increasingly inter-connected world, there is a growing realization of the imperative to protect vulnerable people and livelihoods and to provide for basic human needs and broader human opportunities. In order to do this, achieving water security at the global, regional, national and local levels is a challenge that must be recognized and can be met.

Acknowledgements

The authors wish to acknowledge the invaluable insights provided by John Briscoe, Jerry Delli Priscoli, Mark Rosegrant, Dale Whittington and Ramesh Bhatia. This work builds on the authors' contribution to the 4th World Water Forum, the Theme Document "Water for Growth and Development" (Grey & Sadoff, 2006).

References

Allan, J. A. (2003). Virtual water - the water, food and trade nexus: useful concept or misleading metaphor? *Water International*, *28*, 4–11.

Barbier, E. B. (1997). Introduction to the environmental Kuznets curve special issue. *Environment and Development Economics*, *2*, 369–381.

Basson, M.S, Allen, R.B., Pegram, G.G.S. & van Rooyen, J.A. (1994). *Probabilistic Management of Water Resources and Hydropower Systems*. Water Resources Publications, LLC, Highlands Ranch, CO.

BBC News (2005). BBC World News Website, July 1, 2004, Viewed on 23 November 2005, http://news.bbc.co.uk/2/hi/south_asia/4737153.stm.

Bernstein, Peter L. (2005). *Wedding of the Waters: The Erie Canal and The Making of a Great Nation*. W.W. Norton & Co, New York.

Bhatia, R., Scatasta, M., Cestti, R. & Malik, R. P. S. (2005). *Indirect Economic Impacts of Dams — Methodological Issues and Summary Results of Case Studies in Brazil, India and Egypt*. World Bank Report. World Bank, Washington, DC.

Bhatia, R., Briscoe, J., Malik, R. P. S., Miller, L., Misra, S., Palainisami, K. & Harshadeep, N. (2006). Water in the economy of Tamil Nadu, India: more flexible water allocation policies offer a possible way out of water-induced economic stagnation and will be good for the environment and the poor. *Water Policy*, *8*, 1–13.

Brown, C. & Lall, U. (2006). Climate and economic development: the role of variability and a framework for resilience. *Natural Resources Forum*, *30*, 4 November.

Dombrowsky, I. (2001). *International Cooperation on the Rhine — A Literature Review*. World Bank draft paper.

Fahhlbusch, H. (2001). *Historical Dams*. International Commission on Irrigation and Drainage, New Delhi.

Falkenmark, M. (2000). Water security for multinational water systems – opportunity for development. *Stockholm International Water Institute (SIWI) Seminar*, Stockholm, August 19, 2000.

Global Water Partnership (GWP) (2000). *Towards Water Security: A Framework for Action*. GWP, Stockholm.

Grey, D. & Sadoff, C.W. (2006). Water for Growth and Development in *Thematic Documents of the IV World Water Forum*. Comision Nacional del Agua, Mexico City.

Hirji, R. & Ibrekk, H. O. (2001). *Environmental and Water Resources Management, Environment Strategy Paper No. 2*. World Bank, Washington, DC.

Hirschman, A. O. (1958). *The Strategy of Economic Development*. Yale University Press, New Haven.

ICOLD (2003). *World Register of Dams*. International Commission of Large Dams, Paris.

International Journal on Hydropower and Dams (2005). World Atlas and Industry Guide. Aqua-Media International, Surrey.

Japan Water Forum (2005). *A Study on Water Infrastructure Investment and its Contribution to Socioeconomic Development in Modern Japan*. Unpublished.

Lautze, J. & Giordano, M. (2006). Does "equity" really matter in international water law? Evidence from Africa. *Colorado Journal of International Environmental Law and Policy*, *17*(1), 89–122.

Miller, B. & Reidinger, R.B. (eds.) (1998). *Comprehensive River Basin Development: The Tennessee Valley Authority*. World Bank Technical Paper #416. The World Bank. Washington, DC.

Reuss, M. (2003). *Federal Water Resources Planning*. Office of History, US Army Corps of Engineers, Washington, DC.

Sadoff, C. W. & Grey, D. (2002). Beyond the river: the benefits of cooperation on international rivers. *Water Policy*, *4*(5), 389–403.

Sadoff, C. W. & Grey, D. (2005). Cooperation on international rivers: a continuum for securing and sharing benefits. *Water International*, *30*(4), 420–427.

Sadoff, C. W., Whittington, D. & Grey, D. (2003). *Africa's International Rivers: An Economic Perspective*. The World Bank, Washington, DC.

Sperling, F. (ed.) (2003). *Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation*. Inter-agency report by the AfDB, ADB, DFID, UK, BMZ, Germany, DGIS, The Netherlands, OECD, UNDP, UNEP and the World Bank.

Stockholm International Water Institute (SIWI) (2005). *2005 Synthesis: World Water Week*. SIWI, Stockholm.

World Bank (2003). *Water Resources Sector Strategy*. World Bank, Washington, DC.

World Bank (2004). *Towards a Water-Secure Kenya: Water Resources Sector Memorandum*. World Bank, Washington, DC.

World Bank (2005). *Republic of Yemen Country Water Resources Assistance Strategy*. World Bank, Washington, DC.

World Bank (2006). *Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia*. World Bank, Washington, DC.

World Commission on Dams (2000). *Dams and Development: A New Framework for Decision-Making*. Report of the World Commission on Dams, Earthscan, London.